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METABOLIC ENERGY COSTS OF USAF EXPLOSIVE ORDNANCE DISPOSAL RENDER SAFE PROCEDURES: FIELD DETERMINATIONS

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May 1991

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NOTICES

The voluntary fully informed consent of the subjects used in this research was obtained as required by AFR 169-6.

This report has been reviewed and is approved for publication.

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13. ABSTRACT (*Maximum 200 words*)

The primary mission of the United States Air Force Explosive Ordnance Disposal (EOD) technicians is to render safe munition--conventional chemical, biological or nuclear--that pose a safety hazard during peacetime as well as wartime. The physical work is quite varied; a specific task may require only a few minutes with minimal physical effort, or may require many hours and be very physically demanding. This study measured the metabolic requirements of two EOD teams performing separate "typical" render safe procedures (RSP) on a chemical bomb. Data show the average work rate was between 0.68 and 0.80 liters of O_2 per min for both RSP operations. This work requirement is considered moderate-to-hard, however, the EOD technician should be capable of performing this type of work on an extended daily basis without accumulating fatigue, provided there are no other external stresses. The extended duration and acute dexterity, both mental and physical, required for successful completion of an RSP operation add a unique and intangible level of difficulty to the metabolic requirements. The data from the present study represents an estimation of the energy required to perform a typical chemical operation RSP and should be useful in making management decisions regarding work tolerance for EOD technicians.

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METABOLIC ENERGY COSTS OF USAF EXPLOSIVE ORDNANCE DISPOSAL RENDER SAFE PROCEDURES: FIELD DETERMINATIONS

INTRODUCTION

Recent efforts in defining the energy requirements of United States Air Force (USAF) ground crew activities have provided valuable information regarding the relative work intensities involved for various operations. Field studies completed thus far include ground crew performing rapid runway repair (RRR) (5), integrated combat turnaround (ICT) for the F-16 aircraft (8), firefighter rescue operations (6), and security police ground defense activities (9). Although, there is also a significant amount of literature describing the energy costs of numerous other physical tasks, little is known about the special work requirements associated with the Explosive Ordnance Disposal (EOD) community. The purpose of this study, therefore, was to characterize the metabolic energy costs of performing various EOD operations.

BACKGROUND

United States Air Force EOD technicians play a critical role in ground operations and in personnel safety procedures during peacetime as well as wartime. The primary mission of the EOD team is to render safe any munition--conventional, chemical, biological, or nuclear--which poses a safety hazard to Air Force personnel. During war, EOD technicians may be called to perform render safe procedures (RSP) ranging from removal of an armed, launch-failed missile hanging from a returning fighter aircraft to clearing munitions from a forward open-base operating air strip (BRAAT). Peacetime activities might include performing an RSP on a chemical leak following a military transportation accident or on an improvised explosive device left on or near a federal government facility. The physical work required of EOD personnel is quite varied. A specific task may require only a few minutes with minimal physical effort, or may require many hours and be very physically demanding. Individual efficiency in accomplishing the mission objective also adds to the variation in energy costs. Due to the variety of tasks encountered in this career field, and the need to restrain the present project's size, it was necessary to select an RSP that would be representative of wartime as well as peacetime operations. This study was, therefore, designed to measure the metabolic energy requirements of an EOD team performing a "typical" RSP on an unexploded chemical ordnance. The data obtained should be useful to management decisions related to work tolerance and body heat production of EOD personnel.

PROCEDURES

In cooperation with USAF EOD Command staff (meeting held at Eglin AFB, Feb 1987), a description of a representative task was written. In brief, the task scenario was described as follows: while on patrol, a ground reconnaissance team found a large unexploded bomb (750 lb, MC-1, Appendix A, Fig. A-1) with a side split releasing a liquid thought to be toxic. Explosive Ordnance Disposal personnel unit was asked to respond, render the bomb safe and dispose of the ordnance.

The exercise began with the report of the incident to the EOD unit office. A 4-person team was briefed with the available information, readied and loaded the appropriate equipment and departed for the incident site. Upon arrival at the general site area, a command post and safety limit-line were established. Two members of the team, already dressed in the ground crew chemical defense ensemble (CDE), traveled down range, and surveyed the incident site. Following a short reconnaissance debriefing to the team chief, the reconnaissance team changed to the Toxic Agent Protective (TAP) ensemble, and returned to the site to perform the RSP. This procedure consisted of gagging and removing the fuse, patching the hole to control leakage, decontaminating the bomb and immediate area, wrapping the ordnance in plastic to ready it for transportation, and then returning to the safe area. This exercise was performed by 2 different teams of EOD technicians on separate days. (See Appendix A for a detailed description of the procedures and photographs of the RSPs performed.)

Subjects

Eleven members of the EOD detachment volunteered to participate in the various components of the study. The group ranged in age from 21 to 39 years. A summary of their individual physical characteristics is given in Table 1.

Aerobic capacity

An estimate of individual maximum aerobic capacity ($\dot{V}O_2$ max) was determined according to the procedures described by Astrand and Ryhming (2) and modified for age according to Astrand (1). The average of three repeat determinations is reported in Table 1 .

ENERGY COSTS OF PERFORMING VARIOUS TASKS

Employing standard indirect calorimetric methods, the metabolic energy required to perform a specific task, or a component part of a large task, was determined from measures of oxygen consumption ($\dot{V}O_2$). Immediately before the beginning of a given task each participant was fitted with a nose clip and mouthpiece, and the 2-way valve and tubing assembly was flushed with expired air. Commencement of the task and collection of the expired air sample into the meteorological balloons began with the turning of the 2-way valve (Fig. A-2, Appendix A). Following completion of the task, the collected mixed expired gas samples were analyzed for percent of oxygen and carbon dioxide with a Perkin-Elmer Medical Gas Analyzer (Model 1200). Ventilation and gas temperatures were determined by passing the contents of the collected balloon samples through an American Meter Company DTM-200 Dry Gas Meter - calibration of the meter over the range of the collected volumes was performed using a Collins Tissot Spirometer. All $\dot{V}O_2$ measurements were corrected to standard conditions and reported in both liters of oxygen consumed per minute ($l\ min^{-1}$) and, milliliters of oxygen consumed per minute relative to individual body weight ($ml\ kg^{-1}min^{-1}$). Metabolic heat production was estimated from the amount of oxygen consumed to perform a given task based on the relationship that approximately 5 kilocalories (kcals) of heat are produced for each liter of oxygen consumed. Data reported are descriptive in nature; therefore, only means and standard deviations are reported.

TABLE 1. PHYSICAL CHARACTERISTICS OF USAF EOD TECHNICIANS

Subject	Age y	Height cm	(in.)	Weight kg	(lb.)	$\dot{V}O_2$ Max (Estimated) (ml kg^{-1} min^{-1})
1	21	167.6	(66.0)	74.0	(162.8)	45.05
2	23	174.0	(68.5)	77.3	(170.1)	41.70
3	32	169.6	(66.8)	73.6	(161.9)	36.62
4	21	175.8	(67.2)	70.9	(156.0)	33.85
5	23	185.4	(75.0)	95.5	(210.1)	34.55
6	31	180.3	(71.0)	81.8	(180.0)	35.05
7	26	172.7	(68.0)	56.8	(125.0)	55.45
8	21	180.3	(71.0)	61.4	(135.0)	48.86
9	28	181.6	(71.5)	80.9	(178.0)	44.82
10	29	172.7	(68.0)	59.1	(130.0)	42.98
11	39	172.7	(68.0)	80.9	(178.0)	36.60
Mean	26.8	175.7	(67.8)	73.8	(162.5)	41.41
S.D.	±5.6	±5.5	(±2.6)	±11.5	(±25.2)	±6.86

RESULTS AND DISCUSSION

Two chemical RSP operations were simulated in the field by 2 different teams of EOD technicians. Although both operations were deemed successful, the metabolic data from the component parts of each RSP were different. Unique team individuality regarding the approach and implementation of the RSP was responsible for these differences. Because of this difference, it was not possible to compare the 2 operations or describe an average energy requirement for a given component of the RSP. A listing of each team's RSP operational components is, therefore, included. Data for time required to complete the task, number of subjects sampled, oxygen consumed, and estimated metabolic heat generated during the RSP are described for the first RSP in Table A-4, Appendix A, and for the second RSP in Table A-5, Appendix A. The reported mean values have been time weighted.

Results indicate that the RSP work requirements range from relatively easy, resting type activities, to strenuous, or hard work levels. To make the concept of easy and hard work requirements more universally understood, Dill (4) categorized work into 3 levels (moderate, hard and maximal) defined as a multiple of the basal metabolic rate (BMR) - the energy cost for an individual at quiet, supine rest. Moderate work included those tasks requiring less than 3 times BMR, hard work required between 3 and 8 times BMR, and maximal work required an effort greater than 8 times the BMR. Dill stated that the maximum average metabolic work rate sustainable for 8 h lies in the upper levels of the hard work category or about 6 to 8 times an individual's BMR. Using a $\dot{V}O_2$ of 0.24 l min^{-1} as an approximation of an average BMR (calculated as 15% of the measured resting metabolic rate; Table A-1, Appendix A) and the guidelines provided by Dill, the categories of work for this sample of EOD personnel are shown in Table 2.

TABLE 2. CATEGORIES OF WORK FOR EOD TECHNICIANS

Category	Oxygen consumption ($l\ min^{-1}$)	Oxygen consumption ($ml\ kg^{-1}\ min^{-1}$)
Moderate	<0.70	<9.5
Hard	0.70 to 1.90	9.5 to 25.5
Maximum	>1.90	>25.5

These data show that the average work rate was between 0.68 and 0.80 liters of O_2 per minute (calculated by taking the average work rate for all tasks) for both of the RSP operations placing the average work requirement in the moderate to hard work category. This level of energy expenditure should be within the capacity of the average EOD technician to perform on extended daily basis without accumulating fatigue, provided there are no other external stresses (i.e., significant thermal loading).

Review of the component tasks of the RSP indicates that peak, short-term work expenditure did not approach the estimated maximal work category (1.9 $l\ min^{-1}$). It is important to emphasize that the exercises conducted for this study were simulations, uncomplicated by the reality of an actual chemical hazard which would significantly increase the total energy cost of the RSP. The majority of the expected increase in energy expenditure would result from an increase in the duration of the RSP due primarily to the extreme caution this life-threatening situation demands. Also, increases in work effort or rate would likely occur due to more difficult conditions than those encountered during this exercise (i.e., ground-imbedded ordnance, fuse inaccessibility, rugged topography, etc). Appendix B contains the energy costs of several additional activities that may be encountered in RSP scenarios not part of the present exercise. These values may be added or subtracted from the procedures presented in this paper to enable management to construct an approximate metabolic cost of a wide variety of RSPs.

Monitoring the thermal stress encountered during performance of the RSP was not an objective of this study; however, the negative impact that body heat storage has upon the performance of EOD tasks cannot be overlooked. The body gains heat through 2 basic avenues: metabolic and environmental. Environmental heat gain may be especially high for the EOD technician.

Explosive Ordnance Disposal work is generally without shelter from potentially high radiant and convective heat loads. Furthermore, much of the work they do is done in the bent-at-the-waist position (Fig. A-3), exposing large surface areas to direct radiant load. EOD technicians are also required to wear a toxic agent, impermeable suit (TAP) which restricts the body's ability to dissipate heat. Heat retention can be further exacerbated if the ballistic projectile (flak) vest is also worn over the TAP suit. The magnitude to which environmental conditions contribute to thermal stress is, of course, dependent upon the prevailing conditions at the time of the exercise.

Metabolic heat gain, as previously discussed, can be estimated by assuming 5 kcals of heat are produced for each liter of oxygen consumed. A minimal amount of continual heat generation occurs from basic bodily functions (see Table A-1, Appendix A). Additional, more significant, heat generation and storage results from the inefficiency of the body in performing physical work (15-20%) and is directly proportional to the intensity of the physical work. Heat storage of greater than 100 kcals is normally felt to be unacceptable. A considerable portion of the metabolic heat produced may accumulate over time due to the inability of the body to dissipate the generated heat through the impermeable toxic agent protection suit; thus contributing to a general perceptual fatigue.

CONCLUSIONS

This study was conducted to measure the metabolic requirements of the individual tasks comprising a "typical" chemical agent RSP performed by EOD technicians. The calculated average metabolic requirement for performing these tasks would be considered moderate when compared to average values found during RRR, and security police ground defense or ICT activities (Table 3). The extended duration and acute dexterity, both mental and physical, required for successful completion of an RSP operation, however, add a unique and intangible level of difficulty to the requirements placed upon the EOD technician. The unique skills required to perform the complex job of the EOD technician must clearly overshadow the apparent moderate physical work requirements measured in the present study.

TABLE 3. REPRESENTATIVE MEAN ENERGY COST FOR SELECTED USAF ACTIVITIES

Task	Workload $\dot{V}O_2$ l/min^{-1}	Heat production kcal/hr^{-1}
Rapid Runway Repair	2.0	600
Security Police	1.5	450
Weapons Loaders (ICT)	1.2	360
EOD Render Safe Procedures	0.8	240
SCPS-M Attendants	0.8	240
Pilots	0.6	180
Resting Level	0.3	90

Although this study was limited in size and scope, the data provide a valid representation of the energy required to perform a typical chemical operation, render safe procedure and should be useful in making management decisions regarding work tolerance and duration for EOD technicians.

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REFERENCES

1. Astrand, I. Aerobic Work Capacity in men and women with special reference to age. Acta Physiol Scand, 49 (Suppl. 169), 1960.

2. Astrand, P. O. and I. Ryhming. A nomogram for calculation of aerobic capacity (physical fitness) from pulse rate during submaximal work. J Appl Physiol, 7: 218-21 (1954).

3. Brooks, G. A. and T. D. *Fahey. Exercise Physiology: Human Bioenergetics and Its Applications.* New York: John Wiley and Sons, 1984.

4. Dill, D. B. The economy of muscular exercise. Physiol Rev 16: 263-291 (1986).

5. Myhre, L. G. and R. D. Holden. Metabolic costs rapid runway repair. USAFSAM-TR in preparation.

6. Myhre, L.G. and D. T. Tucker. Metabolic costs of firefighter rescue tasks. USAFSAM-TR in preparation.

7. Webb, P. Work, Heat and Oxygen Cost,. In J.F. Parker and V.R. West (Eds.) *Bioastronautics Data Book.* NASA SP-3006, 1973.

8. Yousef, M. K. and C. T. Rasmussen. Determination of physiological stresses associated with USAF ground crew activities. USAFSAM-TR in preparation.

9. Yousef, M. K. and C. T. Rasmussen. Field study determinations of workload and thermal stresses imposed on USAF ground crew. USAFSAM-TR in preparation.

APPENDIX A

DESCRIPTION OF RSP OPERATIONS

NOTIFICATION AND TEAM BRIEF

The initial step of the exercise was the team chief briefing to the response team with the information obtained from the notifying party. The metabolic requirement for this activity was minimal since the team members were either sitting or standing during the estimated 15-min briefing period. Rest sitting and standing data for this group are summarized in Table A-1. These values compare favorably with data from other sample groups (3, 7).

TABLE A-1. METABOLIC COST FOR EOD TECHNICIANS AT REST

Activity	N	$\dot{V}O_2$ ($l\ min^{-1}$)	$\dot{V}O_2$ ($ml\ kg^{-1}\ min^{-1}$)	Heat produced ($kcal\ min^{-1}$)
Sitting	11	0.28 ± 0.06	3.74 ± 0.59	1.38 ± 0.31
Standing	11	0.32 ± 0.05	4.28 ± 0.41	1.57 ± 0.24

Values are X ± S.D.

EQUIPMENT LOADOUT

Based upon the information provided during the briefing, the 4-person response team prepares the vehicle to support the operation (the energy cost of this activity can vary widely depending upon the prevailing defense condition (DEFCON) level, as well as, the type and relative location of the equipment in the shop to be loaded into the vehicle). For this exercise, a chemical accident, defense readiness conditions were minimal (DEFCON 0) and the equipment to be loaded (Appendix C) was located in a storage area within 10 m of the open-bed, response vehicle.

The loading task was performed by 3 members of the team; the 4th member, the team-chief, verbally directed the others in the equipment loading procedures. Two load-out exercises were completed by each of 2 teams. The average time for the loading task was about 9 min. The average of the 2 exercises for each team can be found in Table A-2. Metabolic heat generated by this exercise averaged 5.75 kcals min^{-1}.

TABLE A-2. VEHICLE LOADING OF EQUIPMENT FOR CHEMICAL ACCIDENT (DEFCON = 0)

Team member	$\dot{V}O_2$ ($l\ min^{-1}$)	$\dot{V}O_2$ ($ml\ kg^{-1}\ min^{-1}$)	Heat produced ($kcal\ min^{-1}$)
Team A			
1	1.20	16.31	6.03
2	1.26	16.30	6.30
3	0.94	13.21	4.68
Team B			
1	0.67	11.80	3.35
2	1.52	18.79	7.60
3	1.33	13.98	6.65

Response to Incident Site

The metabolic cost of this activity, although not measured in this study, may be obtained from the literature and is estimated to be about 0.68 $l\ min^{-1}$ (8-10 $ml\ kg^{-1}\ min^{-1}$) for this group (3, 7). This activity corresponds to a metabolic heat production of about 3.0 to 3.7 kcals min^{-1}. Time to accomplish this task is completely dependent upon the distance and road conditions from the response position to incident site. For this exercise response time was about 30 min; however, travel times in excess of 3 or 4 h are possible.

Arrival on Site and Dress for Reconnaissance of Site

Upon the arrival at the site a command post was established about 2000 feet upwind from the bomb site. From here the RSP was launched. The work party dressed in the ground crew CDE to perform the reconnaissance task. Table A-3 summarizes the individual results. (Again, this task was made simple for this exercise by the fact that the call-in party was quite detailed in their instructions regarding the location of the downed ordnance. Extensive reconnaissance is frequently necessary since the instructions received from the call-in party are generally nonspecific.) The average group energy cost of dressing in the CDE was 9.38 $ml\ kg^{-1} min^{-1}$ and required about 7 min to accomplish.

TABLE A-3. EOD TECHNICIANS DRESSING IN GROUND CREW CHEMICAL DEFENSE ENSEMBLE (CDE) AND TOXIC AGENT PROTECTIVE SUIT (TAP)

Suit	N	Time (min)	$\dot{V}O_2$ ($l\ min^{-1}$)	$\dot{V}O_2$ ($ml\ kg^{-1}\ min^{-1}$)	Heat produced ($kcal\ min^{-1}$)
CDE	7	6.9	0.70	9.38	3.49
TAP	7	8.5	0.79	10.67	3.94

Mean values.

Reconnaissance

The 3-person work party advanced toward the site to establish the safety staging area and perform the initial reconnaissance of the ordnance. Upon arrival at the safety staging area, 2 team-members unloaded the necessary equipment, created a foot decontamination pit (shuffle pit/hot line), and proceeded to the bomb site to inspect and evaluate the existing conditions; the 3rd member of the work party acted as a safety observer and did not actively participate in the RSP. Noting the ordnance and fuse type, the work party returned to the hot line to brief the team chief and perform a technical specifications search. Depending on the familiarity of the team with the found ordnance the specifications literature search may be brief.

The work party, following the debriefing and specifications search, returned to the bomb site with the necessary equipment to temporarily gag the fuse, contain the leak, decontaminate the bomb and surrounding ground and return across the hot line to the safety staging area to begin preparation for the actual render safe operation. The mean energy cost and estimated rate of heat production for the working party performing the reconnaissance and temporary decontamination were as follows: member B--15.2 ml kg^{-1}, 7.25 kcals min $^{-1}$; member C--8.3 ml kg min, 2.95 kcals min $^{-1}$. Member A was the safety officer, his energy cost, that of standing at rest is reported elsewhere.

Prepare for RSP

To prepare for the render safe operation, the response team removed the CDE and donned the Toxic Agent Protective Suit (TAP or M-3). Energy cost of and metabolic heat produced by this activity are summarized in Table A-3.

Site Preparation and Fuse Removal

Across the hot line and to the incident site the work party carried the equipment they would need to gag and remove the fuse and prepare the hole with a more secure seal for safe transport.

Activities during this phase of the operation again involved individual and combined efforts. The equipment carrying and the laying of plastic beside the bomb for site preparation were cooperative efforts. One member gagged, removed, and decontaminated the fuse (Figs. A-4 & A-5); the other member returned to the hot line to retrieve a forgotten piece of equipment. After returning to the bomb site, the EOD technician began to dig a narrow trench under the center of the bomb to facilitate the hole patching procedure; after 4 min of rather intense digging in very difficult soil (wet, clay rich soil), the effort was abandoned. This phase of the operation could be vastly more difficult and time consuming if the prevailing conditions encountered were not as gracious as they were established in this exercise. Variables such as a subsurface bomb, ground-embedded fuse, difficult digging conditions, remote site accessibility, etc., will profoundly increase the required work and thus the heat generated(see Appendix B to construct costs of additional variables).

The metabolic cost for site preparation and fuse removal task as executed in this exercise were for member B--12.28 ml kg^{-1} min^{-1}, 5.0 kcals min^{-1}, and member C--9.45 ml $kg^{-1} min^{-1}$, 2.7 kcals min. Time required to accomplish this task was about 15 min.

Sealing the Leak

The next task of the operation, following fuse removal, called for a more secure patch to be applied to the hole in the shell of the bomb. This process consisted of a technician applying a plaster-of-paris bandage over a wide area of the bomb casing enclosing the gash or hole (Fig. A-6). The other team member could then decontaminate the bomb and immediate area with a solution and brush (Fig. A-7) before the party returned to the safe area to wait for the solution to neutralize the chemical agent.

This procedure took about 25 min to complete. The metabolic requirements were 11.04 and 9.45 ml kg^{-1} min^{-1} for member B and C respectively. Metabolic heat generated was 4.45 and 2.65 kcals min^{-1} respectively. This procedure is physically demanding on the technicians, not from the intensity of the work requirements, these were not that large, but from the postural position the individual must take to limit the potential exposure to the chemical contaminant. Throughout this procedure the technician applying the sealing wrap is bent at the waist with his/her legs spread apart as wide as reasonably comfortable. The assistant will grasp the belt of his/her team member from behind to offer some support (Fig. A-3). This bent-at-the-waist position exposes a large surface area to the radiant load of the sun, as well as, causing a cephalic shift in blood flow. Neither of these conditions will permit the technicians to work for long periods in this position. Consequently several breaks are needed throughout the procedure depending upon the individuals' tolerance to the conditions.

Wrap to Contain Contaminants

The work party returned to the bomb site through the shuffle pit and spread large (3 mil) plastic sheets beside the ordnance to wrap and contain the liquid contaminant (Fig. A-8). The two technicians, then, positioned themselves beside the bomb to push it (Fig. A-9) onto the plastic wrapping. Continuing to roll the ordnance along the long axis, the team enveloped the bomb at least two times. The excess plastic that gathered at the polar ends of the bomb was twisted and secured with filament tape (Fig. A-10). This procedure sealed the ordnance in a vapor/liquid secure package.

Energy cost of this activity was 1.38 and 0.73 ml kg^{-1} min^{-1} respectively for member A and B. (NOTE: Member A, the former safety officer, exchanged duties with team member C who expressed symptoms of excessive fatigue and hyperthermia). Metabolic heat generated by this activity was about 80-85 kcals for the 12 min of activity.

The energy requirements for this component of the RSP will also be greatly modified by many factors. Work requirements may be reduced if heavy equipment is available to assist the technicians in the leak seal and bagging procedure. Conversely, in situations where the terrain is not accommodating or heavy equipment is not available, the patching and bagging procedure can be very demanding on the technicians, requiring much greater energy expenditures than measured during this exercise.

Final Decontamination and Leak Check

The last element of the exercise was the final decontamination wash and leak check to verify the integrity of the plastic enclosure prior to terminating the exercise. The energy requirements for this task were, for member B and C, (NOTE: Change of personnel) 11.37 and 7.87 ml kg^{-1} min^{-1} respectively. This task produced about 46 kcals of metabolic heat.

Ordnance Removal

At this point of the exercise the wrapped, and decontaminated ordnance would be placed into a shipping container (AGM-12) and filled with water before final closure of the shipping barrel. This sealed container with the wrapped ordnance inside would then be transported for disposal. This activity was not measured due to our inability to obtain the proper container and equipment to support this task. The exercise was terminated following the final leak check and decontamination wash, leaving the ordnance resting on the ground, rendered completely safe and ready for transport.

TABLE A-4. RESULTS OF THE *FIRST* RENDER SAFE PROCEDURE

Task	(min)	Team members involved (n)	$\dot{V}O_2$ (l min^{-1})	$\dot{V}O_2$ (ml kg^{-1}min^{-1})	kcals min^{-1}	Approximate metabolic heat generated during task (kcals)	Approximate cumulative heat generated during RSP (kcals)
Notify/Brief:							
Sitting	15	Group (11)	0.28	3.74	1.37	20	20
Stand		Group (11)	0.32	4.28	1.57		
Equipment Loadout	20	A (1)	0.67	11.80	3.35	70	
		B (1)	1.52	18.79	7.60	150	135
		C (1)	1.33	13.98	6.65	125	
Transportation to Site (Values from literature)	30		0.68	8-10	3.0-3.7	90-110	235
Arrivals/Dress in CDE	15	Group (7)	0.70	9.38	3.49	50	285
Reconnaissance/ Initial Decon	15	B (1)	1.45	15.22	7.25	110	395
		C (1)	0.59	8.34	2.95	45	330
Debrief/Research (Sitting values Used)	20	B (1)	0.28	3.74	1.37	30	425
		C (1)	0.20	3.74	1.37	30	360
Dress in TAP (M3) Based upon group Average	8.9	B (1)	0.79	10.67	3.94	35	460
		C (1)	0.79	10.67	3.94	35	395
Sit Prep/Fuse Removal/(FoP) Hold/Decon Area	15	B (1)	0.99	12.28	4.95	75	535
		C (1)	0.53	9.45	2.65	40	435
Decon Effect Wait (sitting values used)	30	B (1)	0.28	3.74	1.37	40	575
		C (2)	0.28	3.74	1.37	40	475
Plastic Wrap Bomb One end with tape	12	A (1)	1.38	17.09	6.90	85	660
		B (1)	0.73	13.95	3.65	45	520
Secure other end and Sides/Contamination Check Test	12	B (1)	0.92	11.37	4.60	55	715
		C (1)	0.44	7.87	2.20	25	545
Total Time	3.2 hours		Average=0.68	Average=9.2	Average=3.4	Individual Totals	(B)=715 (C)=545

TABLE A-5. RESULTS OF THE *SECOND* RENDER SAFE PROCEDURE

Task	(min)	Team members involved (n)	$\dot{V}_{O_2}$ (l min^{-1})	$\dot{V}_{O_2}$ (ml kg^{-1}min^{-1})	kcals min^{-1}	Approximate metabolic heat generated during each task (kcals)	Approximate cumulative heat generated during RSP (kcals)
Notify/Brief:							
Sitting	15	Group (11)	0.28	3.74	1.37	20	20
Stand		Group (11)	0.32	4.28	1.57		
Equipment Loadout	20	D (1)	1.20	16.31	6.0	120	
		E (1)	1.26	16.30	6.3	125	135
		F (1)	0 94	13.21	4.7	95	
Transportation to Site (Values from literature)	30		0.68	8-10	3.0-3.7	90-110	235
Arrival/Dress in CDE	15	Group (7)	0.70	9.38	3.49	50	285
Reconnaissance	15	E (1)	0.89	11.55	4.45	65	350
Initial Leak Stop		F (1)	0.83	11.15	4.15	65	350
Debrief/Research Group	5-30		0.28	3.74	1.37	20-45	385
Mean(Sitting Values Used)			0.28	3.74	1.37	20-45	385
Decontaminate/Gag &	15	E (1)	0.94	11.14	4.70	70	455
Remove Fuse		F (1)	0.82	13.29	4.10	60	445
30 Minute Wait For	30	E (1)	0.28	3.74	1.37	40	495
Recon Effect (Group Mean Sitting Values Used)		F (1)	0.28	3.74	1.37	40	495
Attach Leak (PoP)	7	E (1)	0.78	10.12	3.90	25	520
Decon 2nd Time		F (1)	0.77	10.79	3.85	25	510
Dress in Tap (M-3)	8-9	E (1)	0.79	10.67	3.94	35	555
(Group Mean Values Used)		F (1)	0.79	10.67	3.94	35	555
1st Wrap & Tape & Bomb	10	E (1)	1.08	13.96	5.40	55	610
		F (1)	1.36	18.52	6.80	70	625
2nd Wrap & Tape & Bomb	10	E (1)	1.04	13.46	5.20	50	660
		F (1)	1.10	14.92	5.50	55	680
Leak Test &	15	E (1)	0.45	5.88	2.25	35	695
Final Taping		F (1)	0.68	8.90	3.30	50	730
TOTAL TIME	4 hrs		Average=0.8	Average=10.8	Average=4.0	Individual	(E)=695

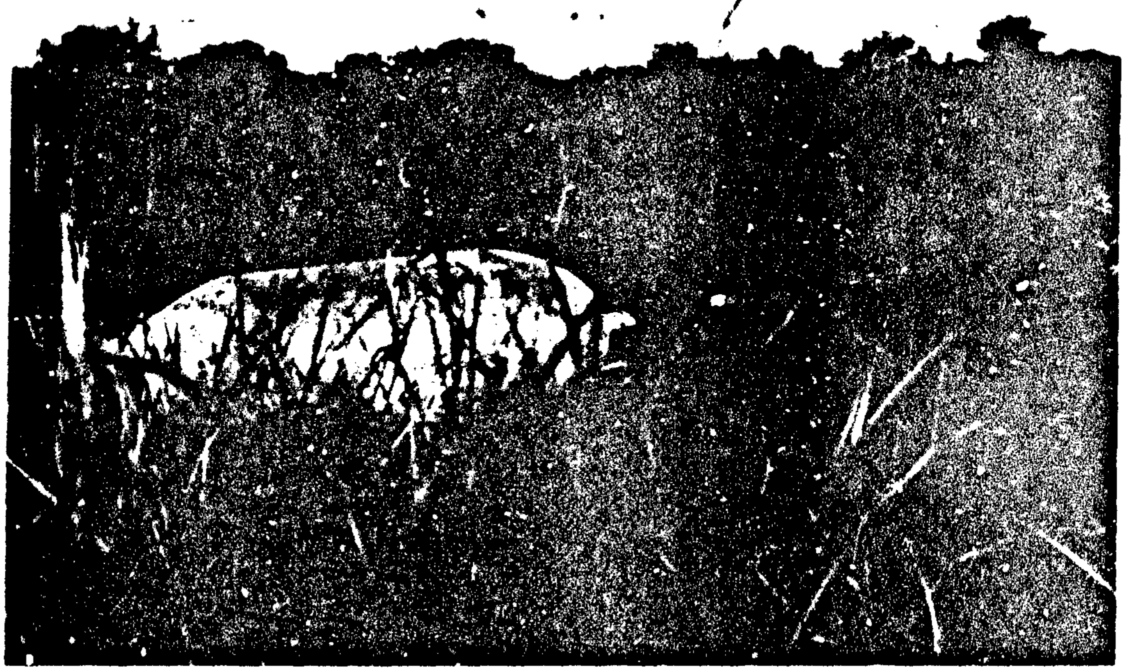


Figure A-1. MC-1, 750 lb Ordnance Position in Field

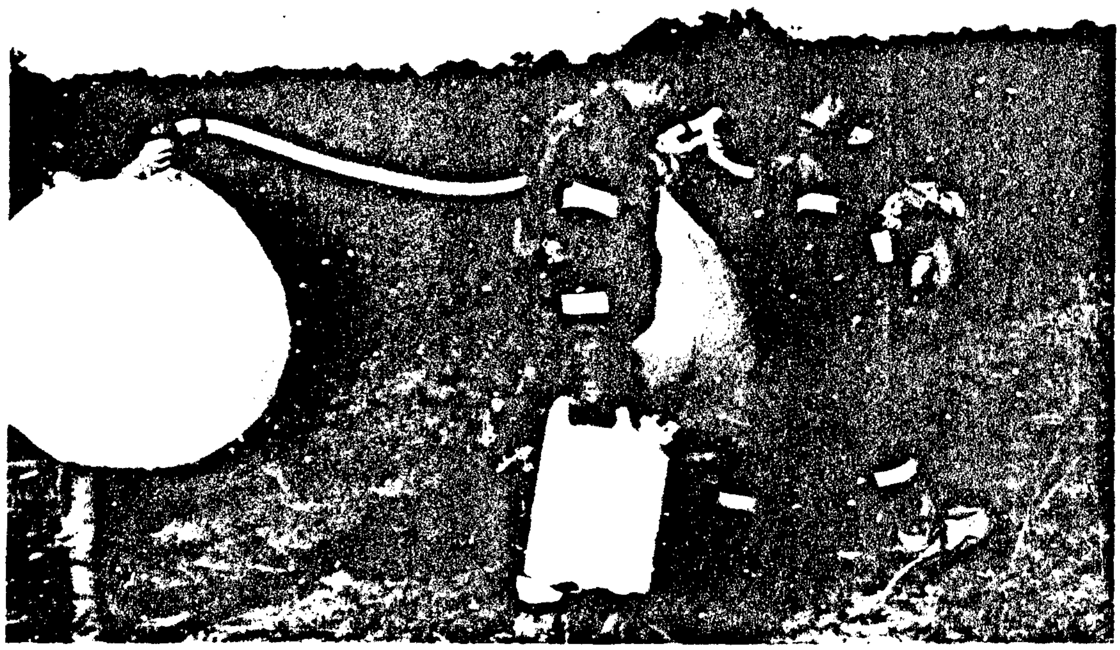


Figure A-2. Expired Air Samples Collected in Meteorological Balloons

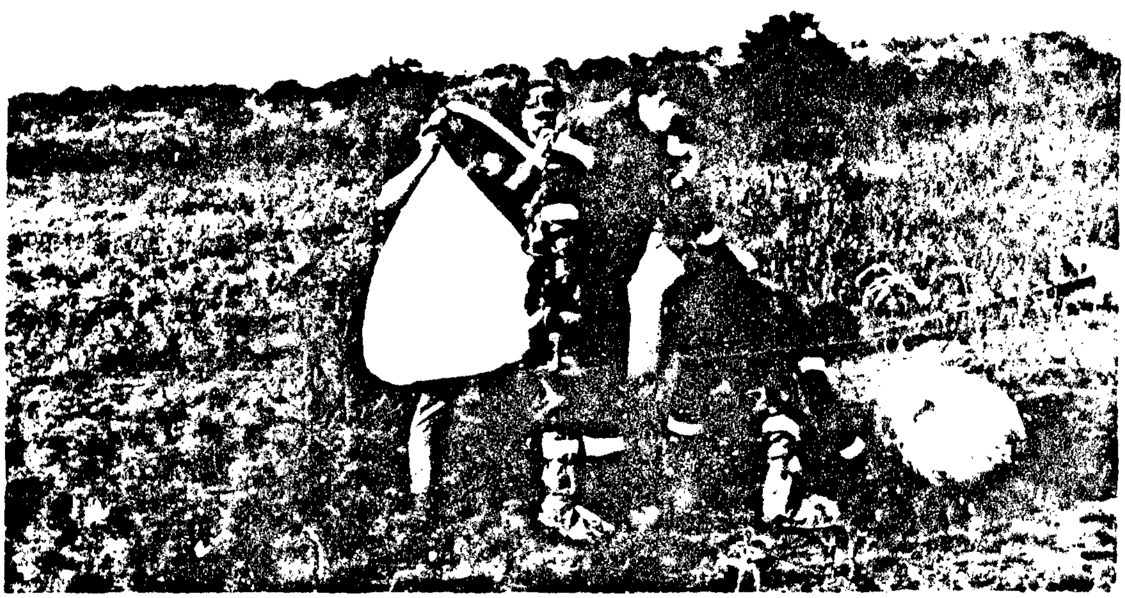
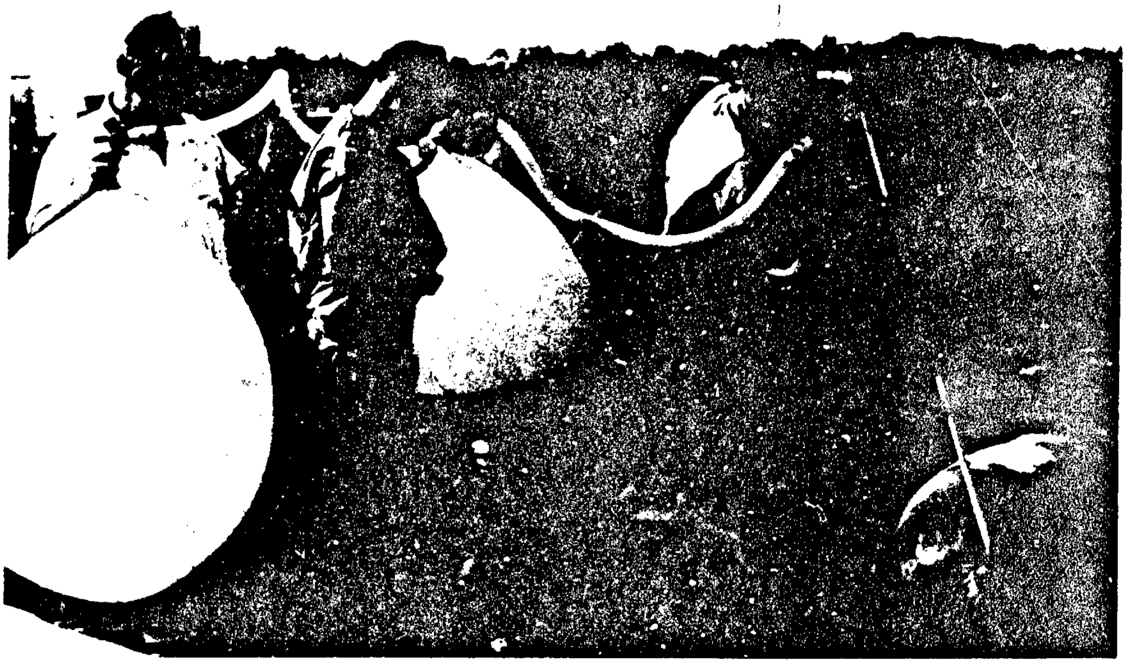


Figure A-3. Explosive Ordnance Disposal Technician Working in Bent-At-Waist Position. Much of the Render Safe Procedure is Performed in this Position to Reduce Self Contamination

Figure A-4. Explosive Ordnance Disposal Technician Gagging The Fuse Before Removal

Figure A-5. Explosive Ordnance Disposal Technician Removing The Gagged Fuse

Figure A-6. Explosive Ordnance Disposal Technician Sealing the Hole in Ordnance Casing with Plaster of Paris



A-7. Explosive Ordnance Disposal Technician Decontaminating the Ordnance and Immediate Area with Solution Wash

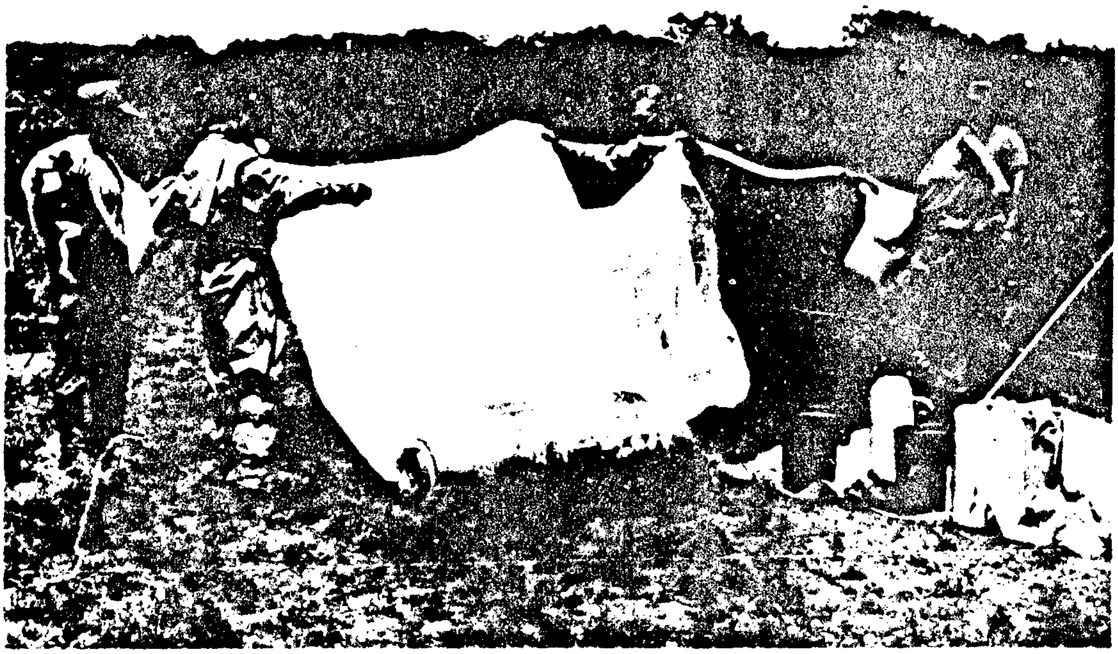


Figure A-8. Explosive Ordnance Disposal Team Members Spread Plastic Wrap

Figure A-9. Render Safe Team Members Roll Ordnance onto
Plastic Sheet to Contain Contaminants

Figure A-10. Technicians Wrap and Secure Ends of Plastic to Completely Seal Ordnance

APPENDIX B

ESTIMATED* ENERGY EXPENDITURES FOR PERFORMING A VARIETY OF TASKS RELATED TO THE EOD MISSION

Activity	$\dot{V}O_2$ (l min^{-1})	$\dot{V}O_2$ (ml kg^{-1}min^{-1})**	Approx. heat produced (kcals min^{-1})
Sitting (Relaxed)	0.32	4.4	1.6 (1,5)
Sitting (Writing)	0.40	5.4	2.0 (5)
Standing (Relaxed)	0.37	5.0	1.9 (5)
Driving			
Auto Moderate Traffic	0.64	8.7	3.2 (5)
Truck Moderate Traffic	0.66	8.9	3.3 (5)
Hand Assembly Tasks			
Standing			
Moderately Difficult	0.71	9.6	3.6 (5)
Hand Tasks			
(Bending at Waist)	1.05	15.0	5.3 (4,5)
Walking			
Flat			
Slow	0.69	9.3	3.5 (3,4,5,6)
Moderately Fast	1.2	16.2	6.0 (3,4,5,6)
Rapid	2.1	28.4	10.5 (2,3,6)
Walking Up a Moderate Slope			
No Load	1.8	24.3	7.0 (4,5)
Carrying 10 kg	2.8	28.2	10.4 (4,5)
Walking (flat/moderate pace)			
Fatigues	1.3	18.1	6.7
Groundcrew CDE	1.7	23.4	8.7
Toxic Agent Suit (M-3)	1.5	19.9	7.3
Bomb Suit (BBS-3)	2.3	30.6	11.3
Walking Up Stairs			
Moderate Pace	2.2	29.8	11.0 (4,5)
Rapid Pace	3.7	49.7	18.3 (4,5)
Raking/Hoeing	1.25	17.0	6.3 (1,2)
Shoveling			
Sand	1.30	18.0	6.5 (5,6)
Broken Dirt	1.54	20.9	7.7 (2,6)
Rocks	1.60	21.8	8.0 (2,4)
Digging			
Broken Ground	1.83	24.8	7.2 (2,5,6)
Packed Ground	2.13	28.8	10.7 (2,6)
Pick Axe	1.97	28.0	9.8 (1,2)
Jack Hammer Operation	1.50	21.0	7.4 (1,5)
Push Heavy Object By Hand (>75LB)	1.97	28.0	9.8 (2,5)

* Information provided was compiled from many sources. These data represent an estimated value for a given task and should be used only as an *approximation* of the energy cost for that task.

** The average mass (73.8 kg) of the participants in this study was used to calculate this value.

*** Sources: (1) Banister, E.W. and S.R. Brown, "The relative energy requirements of physical activity" Jr., H.B. Falls (ed), Exercise Physiology, Academic Press, N.Y. 1968; (2) Fox S.M., J.P. Naughton and P.A. Gorman, Physical Activity and Cardiovascular Health II; The Exercise Prescription; Frequency and Type of Activity. Modem Concepts of Cardiovascular Disease, 41:1972; (3) Howley, E.T. and Glover M.E. The Caloric Costs of Running and Walking One Mile for Men and Women. Medicine and Science in Sports. 6:1974; (4) Shilling, C.W. The Human Machine, U.S. Naval Institute, Annapolis, M.D. 1955; (5) Webb,P. Work, Heat and Oxygen Cost, in J.F. Parker and V.R. West (eds) Bioastronautics Data Book. Nasa SP-3006, 1973; (6) Wilmore, J.H. Athletic Training and Physical Fitness, Allyn and Bacon, Boston, MA, 1977.

APPENDIX C

EQUIPMENT LOADED ON TRUCK FOR CHEMICAL OPERATION

Equipment item	Quantity loaded	Kilograms	Weight* pounds
A-3 Bag/Readiness Gear	4	**24.9	54.7
Web Gear	4	3.4	7.4
Helmet	4	1.6	3.6
Flak Vest	4	4.6	10.6
Binoculars		1.1	2.3
Camera (SX-70 in container)		3.6	8.1
Cording on reel (1000 ft)		4.6	10.2
Demolition Kit		47.3	104.2
Firing wire on reel (500 ft)		6.9	15.3
First Aid Kit		4.1	9.0
High Explosives Kit		2.4	5.4
Microfiche Viewer		8.4	18.5
Pioneer Kits			
Box 1		51.6	113.9
Box 2		53.0	116.8
Plaster of Paris Patch (roll)	4	0.2	0.5
Plastic Sheeting (2 mil) (roll)		4.1	9.0
Radio (MX 300-R)	4	1.1	2.4
Road Kit		31.4	69.2
Sand Bag Kit (w/o sand)		8.9	19.6
Shovel	2	2.0	4.3
Tape (1 roll each monofilament, electrical and masking)		0.7	1.5
Tarp (Canvas 15 * 20 ft)		19.5	42.8
Technical Orders		7.2	15.9
Toxic Agent Protective Ensembles (M-3)	4	9.0	19.8
Water Jugs (w/water)	2	20.8	45.7

* Weights are for individual Equipment Items.

** Numbers in parentheses describe the total number loaded. To get total weight loaded, multiply quantity loaded by the individual item weight (i.e., (4)x(24.9) = 99.6 kg)

* U. S. GOVERNMENT PRINTING OFFICE: 1991--561-053/40057